Exploring the Limitations of Impact-Based Decision Support Services Based on Remote Sensing Using High-Resolution Hail Reports

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Hail Impact-Based Warnings

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LAT...LON 4047 9307 4022 9316 4025 9337 4027 9337
      4027 9343 4032 9375 4048 9375
TIME...MOT...LOC 2316Z 273DEG 36KT 4036 9364

TORNADO...POSSIBLE
HAIL...1.50IN
WIND...60MPH
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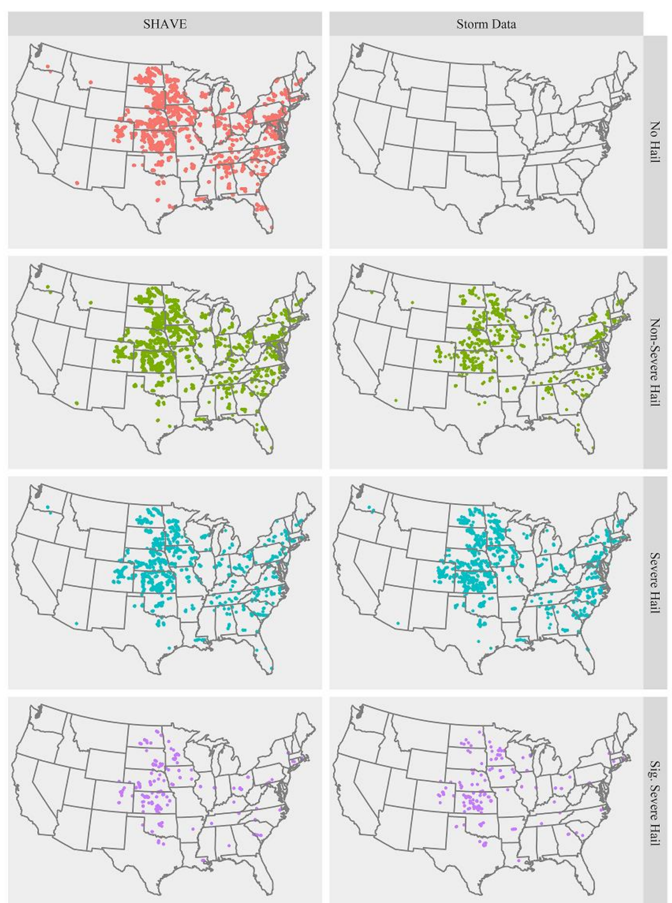
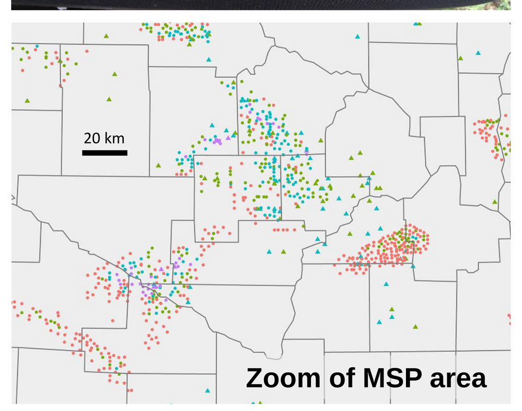
Blair et al. (2017) found hail sizes in severe thunderstorm warnings were lower than the observed maximum size as determined by very high spatial resolution observations from mobile observers. Further, adjustments to hail size within warnings were reactive to received reports.

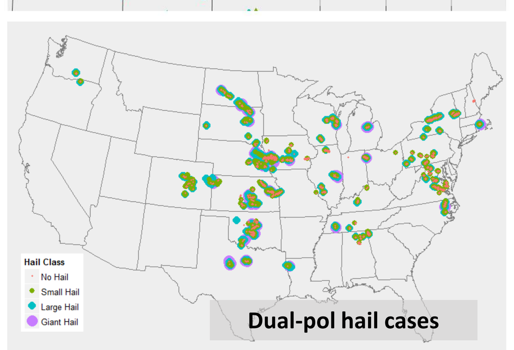
Good hail identification extends beyond warnings, as a number of interests (e.g., insurance) are concerned with not only the maximum hail size, but accurate spatial extents of different hail sizes.

So what radar-based techniques are best for hail sizing?

Data

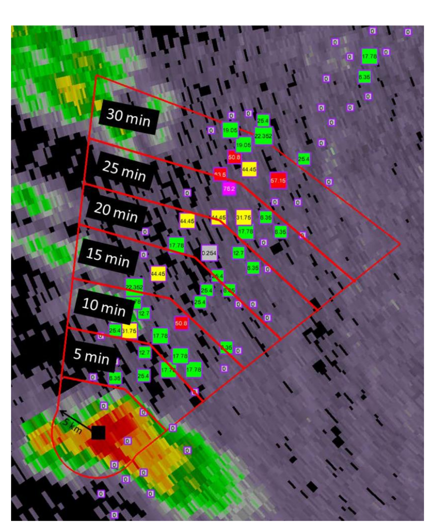


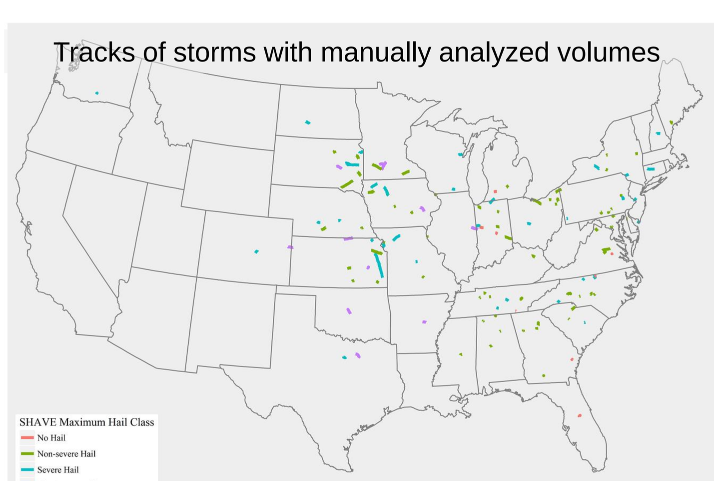




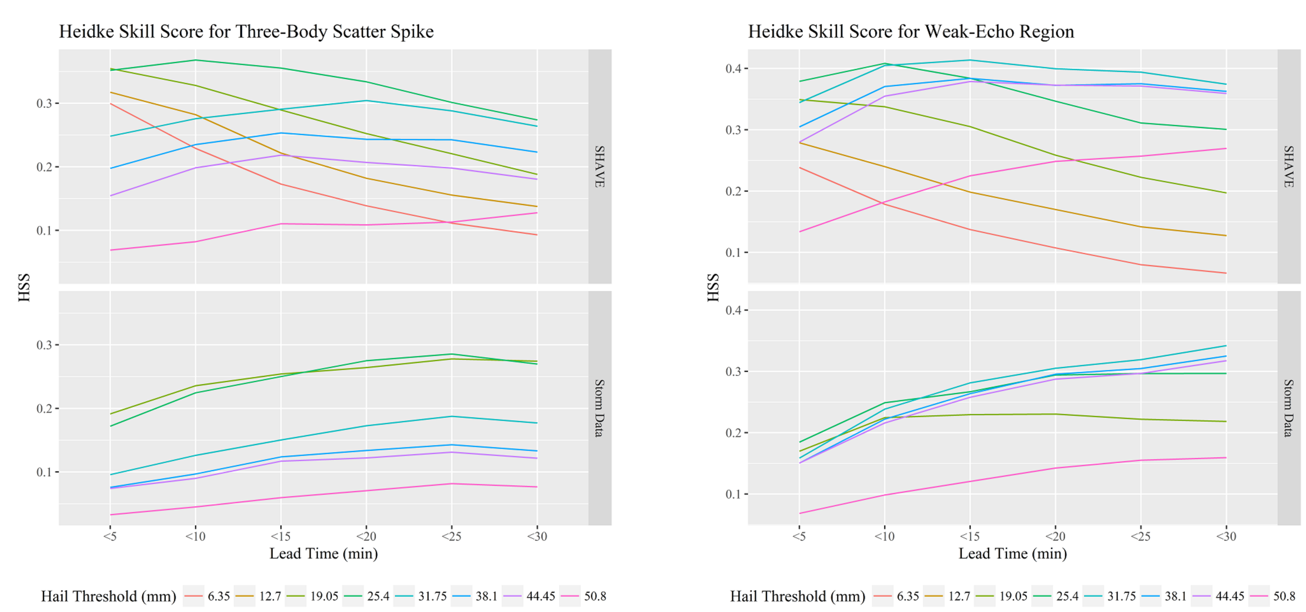
389 operations from the Severe Hazards Analysis and Verification Experiment (SHAVE; Ortega et al. 2009) yielding a total of 21,184 reports: 9,917 'no hail', 7,133 non-severe, 3,648 severe hail, and 486 sig.-severe hail reports. Each report was paired to a number of multi-radar, multi-sensor (MRMS) grids. 79 operations between 2010 and 2014, near dual-pol WSR-88D radars also used. A total of 3,217 reports were used for dual-pol comparisons: 1,115 'no hail', 1,150 non-severe, 786 severe, and 206 sig.-severe hail reports)

131 single-pol operations that had consistent spacing were selected for a volume-by-volume analysis. 1,417 volumes were manually analyzed for hail and updraft proxies, and reflectivity heights. The volumes were paired with near-storm environment and MRMS data. Reports were paired to storm locations in each volume through storm motion-based search technique, with a maximum lead time of 30 minutes.

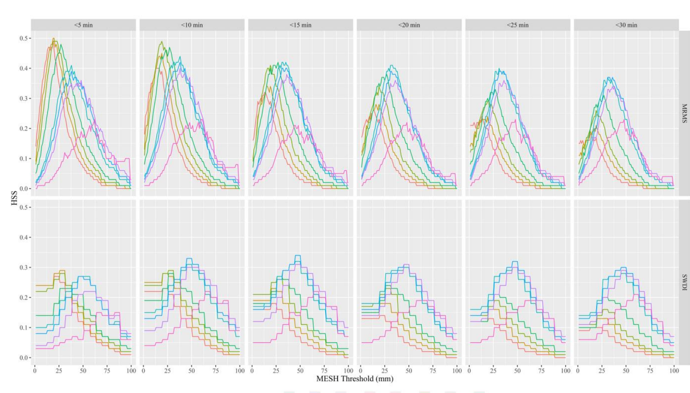




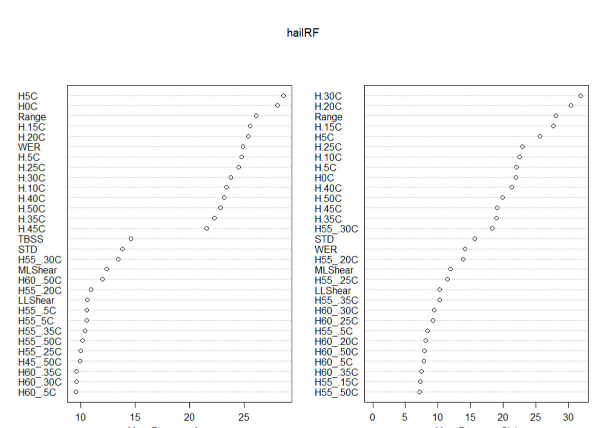
Nowcasting Hail



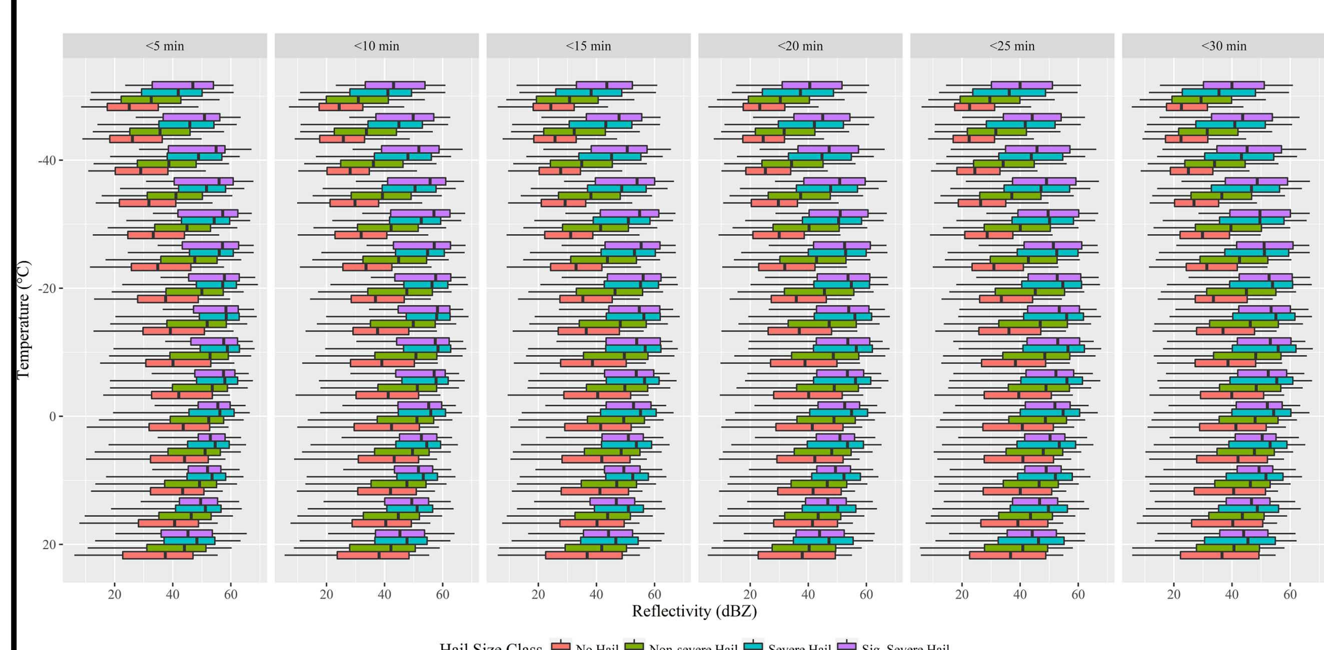
Hail (TBSS; left) and updraft (WER; right) proxies show peak skill at lead times less than 15 minutes.



The maximum MRMS MESH value within 5 km of the analyzed storm shows highest skill for small hail sizes at short lead times.



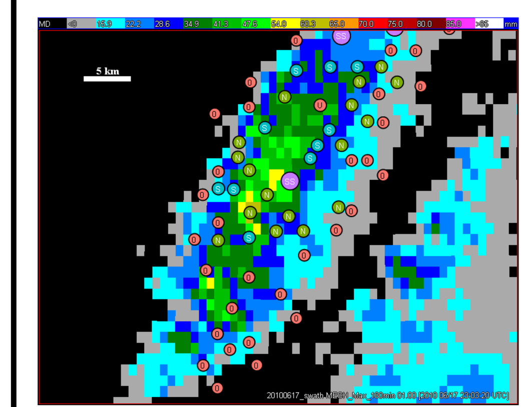
A random forest was created using the data from the tracked volumes. The random forest performed well with an accuracy score of 0.7889. Interestingly, in terms of model accuracy and node purity, the environmental variables were much more important than the radar reflectivity variables.



Vertical reflectivity profiles of MRMS reflectivity show large overlap of the distributions for different hail size categories. Separation of the distributions occurs at colder temperatures (i.e., higher heights) and generally those heights are well above the 0°C level. The separation is also best between the larger hail size categories and 'no hail.' Adjacent categories typically have large overlaps of ~50% of the distribution.

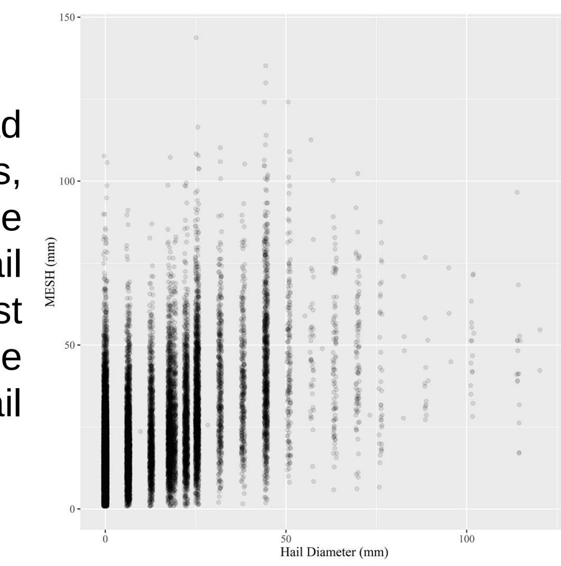
The skill scores and profiles show a limitation in providing impact-based information about hail via radar data: storms producing different hail sizes can have very similar characteristics.

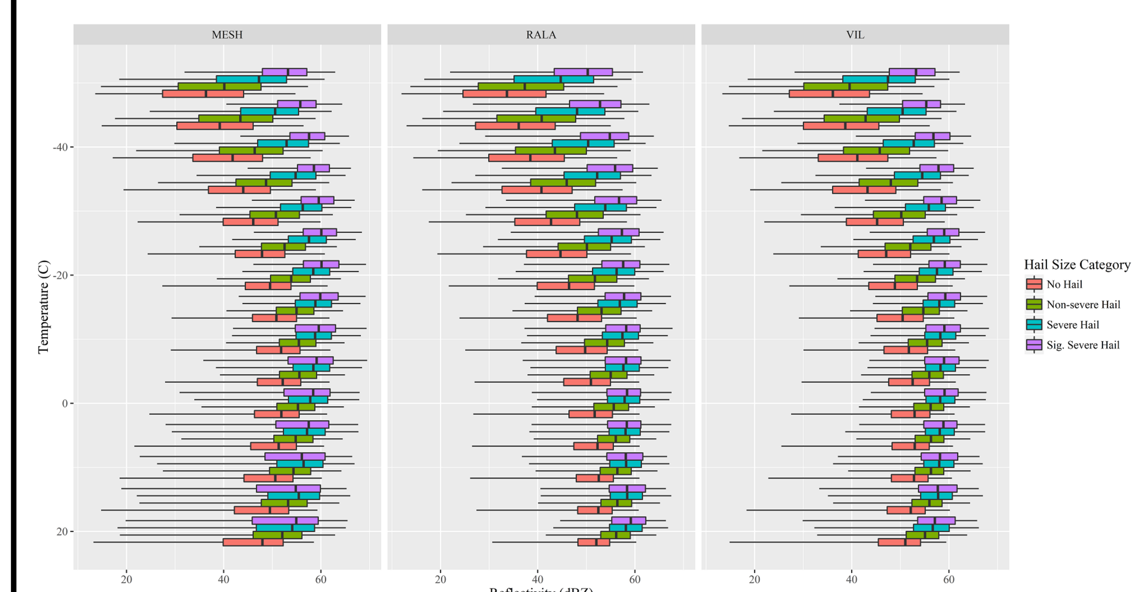
Post-event Analysis

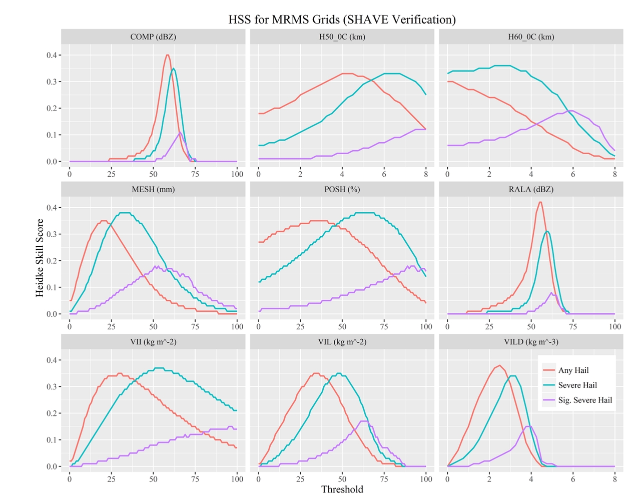


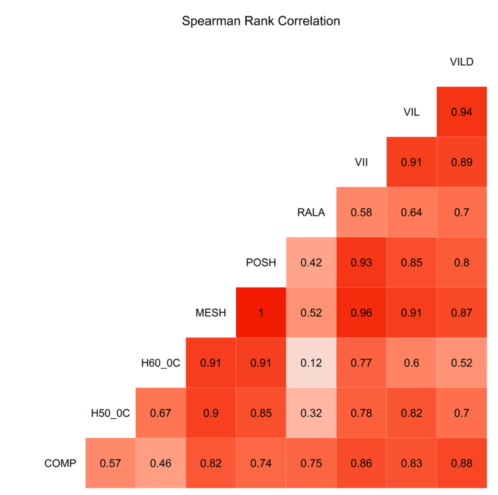
MRMS grids can be accumulated over time, using the maximal value that occurred at each grid point, to depict storm tracks and potentially define the spatial extent of hailfall and the size of that hail.

MESH values show a broad range for given hail diameters, effectively removing the possibility of specific hail sizing. The skill scores suggest it's better to threshold the MRMS grids for general hail size category





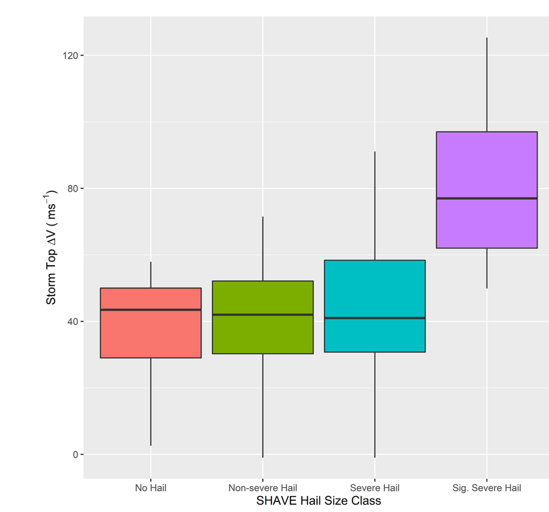


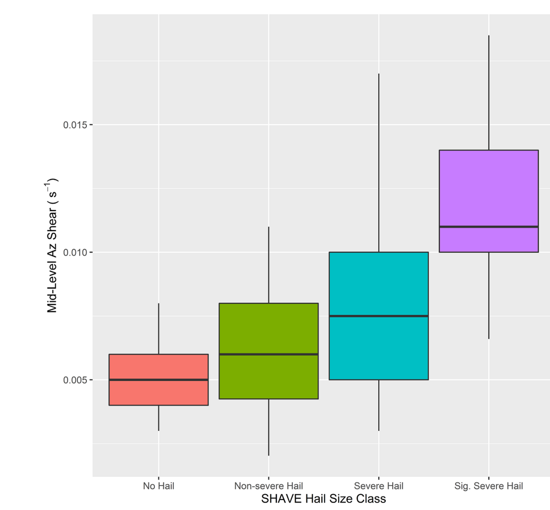


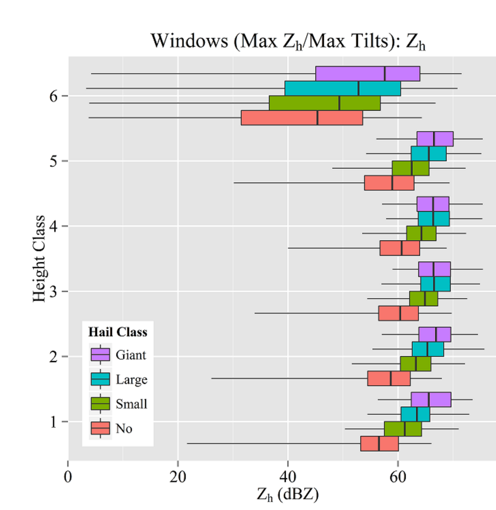
All MRMS products showed similar skill, which may be a result of the high correlations among the products. The high correlations also limit potential combinations of MRMS reflectivity-derived products to enhance the skill in hail discrimination

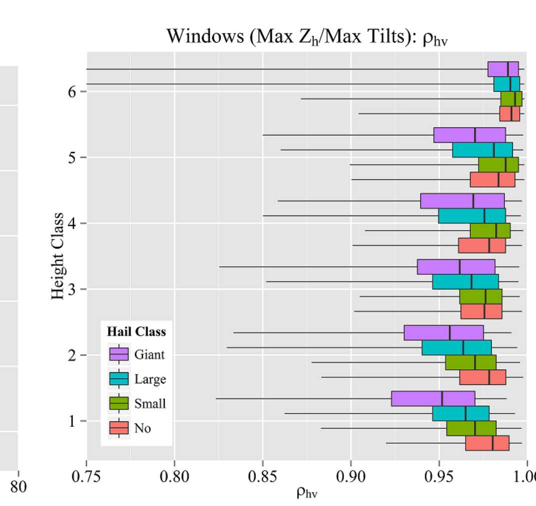
Evaluating the maximal values of several attributes along the tracked volume paths, storm-top ΔV and mid-level azimuthal shear showed distinct increases in the distributions of the values for sig.-severe hail sizes (right).

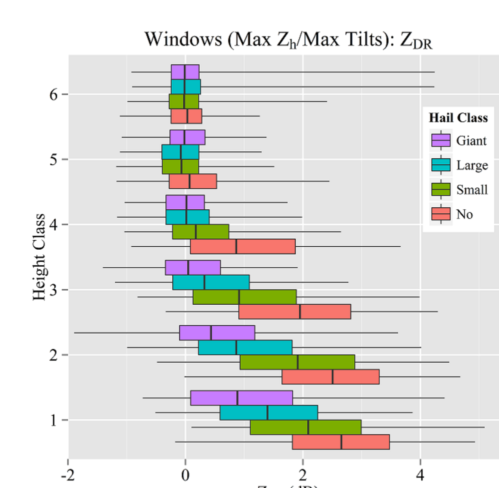
The broad range of MESH values per hail diameter is easily explained from the broad overlap present in the vertical reflectivity profile distributions (left). As with the profiles for the tracked volumes, the different profiles at the time of different maximal values of the MRMS grids show the most separation for 'no hail' compared to the larger hail size categories, and at heights well above the 0°C height. Even for post-analysis, this large overlap limits the potential information to be pulled from even sophisticated algorithms using the vertical profile.











Vertical profiles of polarimetric variables. Z-Z_{DR} pairing seemed to show best discrimination for hail size. A fuzzy-logic scheme using these three variables outperformed the current single polarization algorithm with CSI scores of 0.543 to 0.324 (Ortega et al. 2016).

Discussion

The analyses show that for accurate information for use in impact-based decisions, several considerations and research avenues must be taken. First, are the data, especially the verification data, sufficient to evaluate the impact-based information being delivered? Here, *Storm Data* provides a distinctly different evaluation of the skill of the evaluated products than when using SHAVE. Second, have the products used been evaluated in a way similar to their use in providing impact-based information? Nowcasting hail versus providing a post-analysis map of a hail event are distinctly tasks. Thus, the process of evaluating a product for nowcasting capabilities should be distinctly different than for post-event applications. Traditionally, algorithms are evaluated using a simple space and time radius matching of reports to the product, which is most likely overly simplistic if trying to evaluate specific, impact-based information. Third, have previously assumed "rules" been properly evaluated? For hail, reflectivity heights have been a solid rule of thumb for decades, yet a random forest model was developed that all but showed little importance of the reflectivity variables. Further, the vertical profiles show the limitations for general sizing into categories, so the limitations on specific hail sizing is even greater.

References

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